passing is comparable to that represented by the coming of the ice age. As a result of the advance in technology, such vast changes in the environment of man have crowded in upon him within a period of a few generations that they can well be compared to the changes following upon the advance of the ice age glaciers. It is only the unprejudiced employment and courageous development of his thinking capacity, the determined cutting loose from hampering albeit time-honored dogmas and wishful thinking, which can save mankind now as then.

Several years ago, when the global nature of the present war began to become apparent, an American newspaper published a cartoon showing a pair of apes in a tree looking down over a war-devastated earth and asking each other doubtfully: "Shall we start all over again?" Of course, life would go on even if man were to succumb to the forces he himself has unleashed. But this need not happen, and to prevent it philosophers and intellectuals must by the power of their thoughts bring order into existing chaos and, by recognizing the reality of today and tomorrow, create the essential conditions for saving at least a part of inherited human values. The call of this task is still drowned out by the noise of battles, but it is so urgent that it summons all spiritually inclined people in every nation. We have ended up by seeing each other no longer as actual human beings but only as the exponents of differing ideologies and have in this respect, too, sacrificed reality to ideology. The conflict between the various truths and ideologies has contributed toward the forming of the present disaster. It is by way of the common struggle for the comprehension of the reality common to all that the path out of the catastrophe leads. The fact that mankind has gone berserk must not destroy our confidence in the power of thought: it should strengthen our will to make use of it to overcome the present chaos.

# TREMBLING EARTH

By REV. FR. ERNEST GHERZI, S.J.

*The Director for meteorology and seismology at the Observatory of Zi-Ka-Wei in Shanghai presents the results of more than twenty years of research on a little-known topic.*

IF the old Chinese legend is true and if there is a dragon who sleeps under the earth's crust, then his sleep must be very restless. His cloak and blankets of crystalline or sedimentary rocks are vibrating all day long, even when no major seismic upheaval is under way. Seismologists call these continuous but small tremors the "microseisms" of the earth (from Greek *mikros* = small, *seismos* = earthquake).

A sensitive seismograph will register these small displacements of the earth's particles all day long. Their motion averages a few microns, that is, a few thousandths of a millimeter, but their presence on the seismograph's recording paper is an object of scientific interest.

These "tremors" can be divided into four classes.

*The first class* consists of the small vibrations caused on the seashore by the breaking of the ocean waves. These microseisms are not very apparent most of the time. It is only when the big surf rolls in that the tiny saw-teeth become visible on the records. They have a period of one or two seconds, but the amplitude is often negligible. (FIG. 1)

*The second class* of microseisms is caused by the cold. The contractions of the earth's crust under the influence of freezing are clearly shown by the seismograph. To this day it is a mystery how waves of so long a period—one to two minutes—can be registered by the instrument, which has a very reduced sensitivity for these long-period oscillations. That would mean a really great displacement of the ground during the freezing period of the upper superficial crust. During sunny winter days, one can easily distinguish on the seismograph the hours during which there was freezing and the hours during which there was sunshine and a warmer temperature. (FIG. 2)

*The third class* is the one allotted to the vibrations of buildings, trees, etc., caused by the impact of big winds. These oscillations are very irregular and, as a matter of fact, most of the time merely a proof that that particular seismograph installation is not quite what it should be. In the case of instruments well placed and isolated from the superficial layers of the crust, these "wind made" microseisms are almost entirely absent.

*The fourth class* of minute earth tremors is the most interesting one, and its analysis has proved a source of very useful conclusions. For many years this type of microseism has been discussed in international seismological literature. A sort of intellectual battle over this subject is still partially going on, but for us at Zi-Ka-Wei Observatory it seems a settled question, as the corroboration of the explanation we have given has, for some twenty years already, been quite constant and reliable.

These microseisms appear in seismological recordings as a series of succeeding groups of regular sinusoidal oscillations. All over the world, these oscillations have an almost constant period of four to six seconds. This period remains the same even when the amplitude has greatly increased. Each group of oscillations appears about every minute. The number of oscillations which make up each group can vary from three to ten. (FIG. 3)

For many years, the generally accepted explanation was that offered by Dr. Wiechert, the well-known German seismologist; namely, that the oscillations were caused by the breaking of big waves over rocky coasts during cyclonic weather. This, we might notice, did not explain the four- to six-second period of the oscillations, nor the approximate period of one minute for each group of oscillations. Nevertheless, this explanation was admitted and adhered to like an axiom.

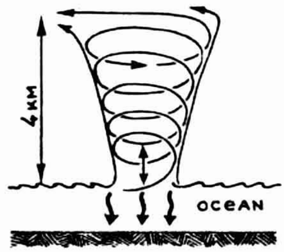
### A NEW THEORY

At the Zi-Ka-Wei Observatory in Shanghai we were in possession of a very sensitive Galitzine seismograph for the vertical component of the motion of the ground, and so we ventured to check the old theory of these special microseisms. We found that during the long hours and even days when very strong winter monsoons blow, with plenty of high seas breaking over the rocky coasts of the Chusan Islands (southeast of Shanghai), no registration whatever was obtained of these microseisms so commonly associated with the phenomenon of surf breaking over the seashores. This fact was already extremely interesting.

Then we noticed, later on in the season, that with a typhoon center located by our weather service at 2,000 kilometers to the southeast or east of Shanghai, the seismological registrations clearly showed the appearance of these one-minute period groups of four- to six-second period oscillations.

Reports received from the light stations of the Chusan Islands also revealed that at that moment the sea was very smooth and that not even a distant swell was felt yet.

Having collected these registrations for two years, we decided to enter the fray and oppose the old explanation of Dr. Wiechert. In 1925 we submitted to the meetings of the International Geophysical Association a series of our registrations with a paper stating that these special microseisms could not be attributed to the breaking of the waves on a rocky coast but that they were due to atmospheric trouble, in our case to typhoons pounding the ocean surface and in this way shaking the crust below the sea water. We added that the periods of the oscillations revealed the movements of the lower part of the storm striking the surface of the sea. The stormy surface of the ocean acted like a piston pushing down from the top and causing vibrations at the bottom of the sea. The four- to six-second period was due to the usual height of the cyclonic air column, and this was also the reason why, although the amplitude increased with the approach of the cyclone, the period of these oscillations did not change.




We added that in Europe one could not check this new theory, since in Europe there is only cyclonic bad weather but no monsoon high seas. We asked the International Committee to put a seismograph on the coast of India, where the monsoon blows very hard for three months and where tropical cyclones or typhoons with their own high seas are also felt. The registrations obtained in such a region would help to ascertain whether our explanation was right or wrong. Seismographs were thereupon placed at the Colaba Observatory near Bombay. We waited a year for the results. Finally they came, and they were quite reassuring. The Director of the Observatory issued a pamphlet in which he stated that by this new device he could now establish the existence of a cyclone, somewhere over the Indian Ocean, without any telegram from ships. He had found that, during the three months of pounding by waves due to the monsoon, special microseisms were never registered. They only appeared when, even with smooth seas along the Indian coasts, there was a traveling cyclone somewhere at large on the open ocean.

Consequently, the first round of the fight was won.

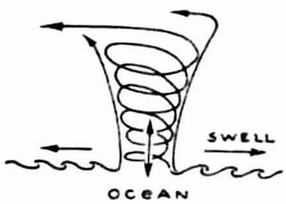
In many other observatories similar research was conducted, and the old explanation was almost generally being rejected. Those who continued to cling to the old theory still failed to explain, as they should have done, the period of the oscillations in question.

Since then we have continued our research and were able to propose to the scientific authorities a few consequences of our theory which proved useful and illuminating.

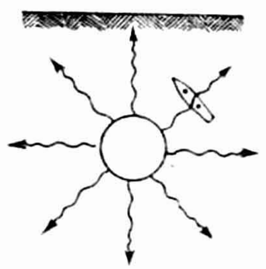
If these vibrating waves of the lower part of the typhoon are the real cause of these registered microseisms of the fourth class, it is obvious that the special period of these oscillations can also give an idea of how high the dangerous part of the cyclone is in the atmosphere. And so it was; by proper calculation of the density and temperature of the air in motion, we found that this height should be around two to four kilometers, rarely higher and only when the period of the microseisms is of about six to eight seconds.

Above this level of around four kilometers, the air should escape from the cyclone column and be of no more danger to airplanes, as the flow of this air should be almost horizontal, although with a high velocity of a hundred and more kilometers per hour.

This theory would also help to forecast the future direction of any storm. It would also explain the phenomenon called the "swell." This special type of sea waves should originate in the center of the storm, not as a result of the cyclonic winds, but owing to the "pumping" of the pressure caused by the bouncing over the ocean surface of the lower part of the cyclonic column. One would then understand why ships are sometimes tossed against the direction of the typhoon gale. One would also understand why these microseisms sometimes almost die out while high waves continue to keep pounding the rocky coast.




Another very useful hint acquired from this theory of the microseisms of the fourth class is that ships will know toward what region they have been drifting when riding a typhoon at sea. With a high swell present they will have been brought away from the center, in the direction of the swell; with no swell existing, they will have been taken along by the prevailing cyclonic gale, toward the center of the storm.



If the "bouncing" of the lower part of the cyclone over the ocean is really the cause of these vibrations of the earth, the aspect of the "swell" disturbance—which, as we have said, is caused also by the cyclone—should reveal a similar grouping of waves with a decided period of five to six seconds.

We tried this check with the enthusiastic collaboration of some officers of the coasting steamers. With all the necessary precautions they measured the period and the sequel of the swell-waves, and we published these figures, which were quite concordant with the registrations obtained on the seismological curves. As these measurements of the period of the swell-waves ran into several thousands, our check seemed to us quite positive.

The reproduction of some of these microseisms as obtained on our vertical-component photographic seismograph will show clearly what we have said. But how big are these vibrations of the earth? They are to be measured in thousandths of a millimeter, and their greatest amplitudes are obtained when the center of the cyclone is close to the seismological station. The oscillations may reach one hundredth of a millimeter; most of the time they are smaller than that.

Can we by means of the registration obtained of the three components of the earth's motion, namely the north to south, the east to west and the vertical, find the location of the advancing typhoon? This question has been put to us many times, but we must confess that such a location is impossible. The arrival of these oscillations at the seismograph does not happen exactly at the same time for the same wave-group. The transverse and the longitudinal vibrations of which these waves of the earth are composed have different velocities of propagation, so much so that the identification of the same group of microseisms on the records is practically impossible.

I would even add that to rely on the intensity of these microseisms in order to ascertain if the cyclone is nearing the station is a risky undertaking, as the typhoon can suddenly increase in its violence or decrease when getting nearest to us. As we have already said, these microseisms may even disappear for some hours if the lower part of the storm ceases to oscillate. Another certain fact is that some of these tropical storms, while remaining stationary, undergo great variations of violence. Consequently, the vibrations of the earth by themselves become of no use for ascertaining the course of the storm, as their intensity varies while the typhoon is not moving.

A rather interesting and useful consequence of the discovery that typhoon winds affect a periodicity of four to six seconds is that any rigging or mast or tower, etc., exposed to such a violent ordeal should not itself possess a period of oscillation of the same value. Otherwise resonance might easily set in and destruction quickly follow.

Many years ago we published a pamphlet, brought out by the former Municipal Council of Shanghai. In it we discussed all the dangerous consequences of this fact for buildings in regions infested by tropical cyclones. These ideas were well received by the civil engineering societies of Europe and America, and it is an amusing thought that seismographic registration can be of use in determining the proper method to adopt in building skyscrapers and wireless towers.

### AIR AND TIDES

Among these microseisms which show by their behavior the motion of big atmospheric disturbances we can also include some other, much slower motions of the ground which have a similar origin. When there is a thundery formation, we know that the heated air tends to rise skyward and may even develop later on into a full-fledged thunderstorm with lightning and heavy showers. This volume of heated air seems to hesitate, to rise, at least so to say, to try to pierce the upper atmospheric blanket which is still normally cold and through which the warmed column must work its way up. If we now consider a very sensitive vertical-component seismograph, we can figure that, if the pressure exerted on the ground by the overlying air changes, the seismograph will be affected, because the elastic layer (rock or special concrete foundations) upon which it is placed will undergo a pendulumlike variation of the compression caused by the weight of the atmosphere; as a matter of fact, this weight will change owing to the upward rise of the warmed column of air just mentioned.

The graph we reproduce shows this elasticity phenomenon quite well. Of course, it is corroborated by the trend of the barometric course, as the barometer will show if the pressure over the ground is changing gradually or with a regular and measurable period. This period is, most of the time, of about one minute. That could help to measure the thickness of the air stratum which is in such an unstable condition. Possibly such a datum might be useful for knowing the altitude of this disturbed and dangerous atmospheric layer. But other physical data must be made available by means of atmospheric soundings if we want to offer a fairly reliable figure. Unfortunately, these data were not available when our registration was obtained. Besides, sending up pilot balloons when a thunderstorm is over the place is a rather difficult feat.

Anyhow, here again in this case of slower motions of the ground the modern seismograph offers very interesting possibilities of research. I even dare to say that these microseisms may perhaps give an idea of how thick the alluvium or sedimentary stratum is upon which the instrument is located. I am sure the people of Shanghai would like to know how thick this mud layer is upon which we live through the bright and dark days of our life, and at what depth we should strike rock.

But these peace-time researches have not yet been possible, and so we can only express the wish that we be able to conduct them as soon as possible!

We might mention that the tides of the earth's crust can also be measured by means of instruments quite similar to our Galitzine seismograph for the vertical motion of the ground. The galvanometric and photographic registration employed can be brought to a very high magnification, namely, to a few million times.

We have never attempted such a measurement, as that would require a special installation, preferably underground, far away from any outside or local disturbance. Here in Shanghai, where we find ground water a few meters or sometimes even less below the surface, any waterproof underground room means a really big expense.

Microseisms offer an interesting and wide field for further research. Indeed, the Zi-Ka-Wei Observatory in Shanghai is studying every slightest vibration of the earth's crust with the same intensity as are other well-known observatories the world over.

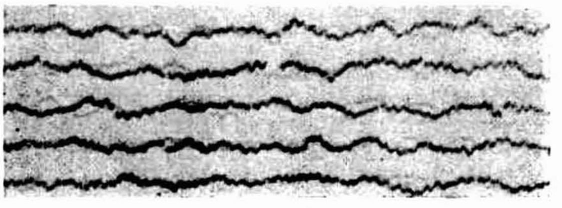


FIG. 1. Microseisms caused by winter monsoon. (Small teeth = waves breaking on shore; longer oscillations = cold contractions of the earth's crust)

[The registration is obtained on a drum revolving and at the same time advancing]

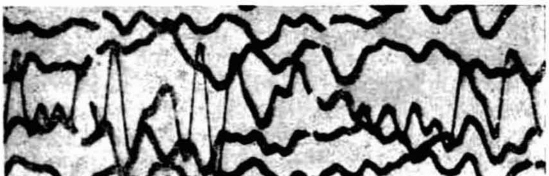


FIG. 2. Microseisms caused by cold

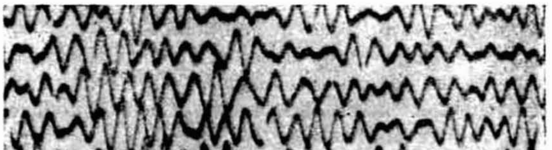


FIG. 3. Microseisms caused by typhoon